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THE TRIASSIC PORTION OF THE SHINARUMP GROUP, POWELL

WHITMAN CROSS[1]

Introduction.—Among the great sedimentary formations or groups of the Plateau Province, described by Powell, Dutton, Gilbert, and others, that one named by Powell the Shinarump is today the least known and occasions the greatest difficulty in correlation. As I have recently attempted to correlate the formations of the Plateau Province with those of the adjoining mountain district of southwestern Colorado, the difficulties in regard to the Shinarump have come prominently to my attention, and it is hoped that a brief review of the subject may be of material assistance to geologists who attack the problem in future.

The Shinarump is the lowest of three formations or groups assigned by Powell to the Trias, the others being the intermediate Vermilion Cliff sandstone and the White Cliff sandstone at the top. The Triassic was thus supposed by him to embrace everything present in the great section north of the Grand Canyon between the upper Aubrey (Pennsylvanian) and the marine Jurassic.

Dutton and other writers have referred the White Cliff sandstone to the Jurassic, and this reference is no doubt correct, since the continuity has been established between this very well-marked formation and the La Plata sandstone of Colorado, which is in angular unconformity with the Triassic and the entire Paleozoic section (4).[2] The

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] Numbers in parentheses refer to the bibliographic list to be found at the end of this paper.

Triassic age of the Vermilion Cliff sandstone has not been directly questioned, neither has it been fully proven, and it will appear in the course of this discussion that there is some slight basis for the suggestion that it is lower Jurassic.

As for the Shinarump group, Walcott long ago found Permian fossils (**24**) in the lower beds referred to it by Powell and possibly Jurassic fossils (**4**) in the upper part, while a Triassic vertebrate fauna occurs near the middle of what Ward refers to the Shinarump (**26**). The question as to the real character, scope, and correlation of this group is then plainly one requiring further study and consideration.

The standpoint from which this review is written is that of several years' experience in the stratigraphic section of southwestern Colorado, with some information as to the gradual changes exhibited by the formations as they pass from the mountain slopes into the adjoining vast area of plain and canyon—the Plateau Province. It may be well to present in the outset the facts of major importance bearing on the topic under discussion and indicate frankly the tentative conclusions I have reached as to their application.

It has been established that the Dolores formation of the San Juan region of Colorado is of Triassic, and probably of upper Triassic age. An angular unconformity has been found below the Dolores by which the whole upper Paleozoic red-bed series and a part of the Pennsylvanian strata are locally cut out. No middle or lower Triassic beds have been found and none demonstrably Permian. The stratigraphic break below the Dolores is thus shown to be of much importance.

The Dolores formation has been traced from the mountains into the heart of the Plateau district along two lines of approach. The most important fact established is that the fossiliferous basal member of the formation extends west and northwest from the San Juan Mountains as far at least as Grand River, in Utah, where the angular unconformity below it is very marked, and 1,500 to 2,000 feet of probable Paleozoic beds are gone at some places. An overlap of the basal Dolores conglomerate from Permian (?) beds directly to the pre-Cambrian complex occurs on the western side of the Uncompahgre Plateau, in Colorado, where it was observed by Peale in 1875. The

fossiliferous lower strata of the Dolores have also been traced down the San Juan Valley nearly to the Glen Canyon of the Colorado, below the Henry Mountains.

While nothing similar to the Dolores fossiliferous conglomerate has been described from the original area of the Shinarump Group in Utah or Arizona, the discovery by Ward (**26**) on the Little Colorado River of the vertebrate fauna characteristic of the Dolores shows plainly that a correlation of great importance is to be anticipated when the requisite studies have been made.

In the literature of geological investigation in the Plateau Province, which is almost wholly of reconnaissance character, a certain bed or zone of strata in many widely separated localities has been called "the Shinarump conglomerate" and its identity in those places asserted. This has been done without much descriptive detail and chiefly on the basis of lithologic character. Now in the Dolores formation the lower zone, embracing all beds found to be fossiliferous, has also a most perfectly diagnostic lithologic phase. This is found almost invariably at the base of, and irregularly developed through, 200 or 300 feet of beds. Those who have worked in the San Juan region have come to apply the convenient field term "saurian conglomerate" to this diagnostic phase because one seldom searches in vain in it for teeth or bone fragments belonging to dinosaurs or to belodont crocodiles.

The peculiar lithologic feature of the "saurian conglomerate" is that it consists mainly of small round gray limestone pebbles, in many places almost pisolitic in appearance, though never showing the structure of true pisolite spheres, and rarely reaching one inch in diameter. The conglomerate is most irregularly distributed, with cross-bedding structure, through sandstone ledges from a few inches to perhaps thirty feet in thickness. The color of conglomerate-bearing ledges is often greenish gray and shales or sandstones of the same tones are common between them. More complete descriptions of the conglomerate zone are given in the Telluride and Rico folios (**1** and **3**).

The upper part of the Dolores formation is of very variable thickness in the San Juan region, owing in all probability to erosion in the ensuing epoch. It thickens westward and has been confidently correlated with the Vermilion Cliff sandstone of the Plateau Province (**4**).

The foregoing brief statement will, it is hoped, be sufficient to show the desirability of tracing the horizon represented by the basal beds of the Dolores formation through the Plateau country, not only to establish the base of the Trias but to discover the most favorable localities for the study of the older, and probably Paleozoic red beds, the full section of which is perhaps not yet known. According to present knowledge the horizon in question is not far below the Vermilion Cliff sandstone in the central and northern parts of the Plateau. In southern Utah and Arizona there is evidence of a decided increase in the thickness of the Triassic beds below the Vermilion Cliff sandstone, sufficient to warrant the suspicion that the true Shinarump conglomerate of the Shinarump Cliffs, while a thousand feet below that sandstone, may still be at the same horizon as the "saurian conglomerate" of the Dolores formation.

We will turn now to a scrutiny of the literature bearing upon the subject.

The Shinarump conglomerate described.—The term "Shinarump conglomerate" appears to have been used for the first time by Powell, in 1873, while describing the geologic structure and naming the topographic features of the district lying north of the Grand Canyon of the Colorado (**21**, p. 457, 458). Powell says that from the Grand Canyon northward one travels over Carboniferous beds to the first line of cliffs, one hundred to four hundred feet high.

> This escarpment is capped by a firmly cemented conglomerate containing many fragments of silicified wood, and over its surface are scattered many like fragments, and sometimes huge tree trunks, which are the remnants of rocks at one time overlying the conglomerate, but now carried away by erosion. Underlying this cap are variegated sandstones and marls. The whole group is probably of lower Triassic age.

In 1875, Gilbert, Marvine, and Howell, of the Wheeler Survey, published the results of their work in the country adjacent to the Colorado River, and refer to the Shinarump conglomerate as something defined by Powell. Their observations covered a wide territory, including that of the Shinarump Cliff, and there seems to be no doubt but that their references are to a single well-defined conglomerate stratum or bed.

Gilbert assigned to the Trias 2,500 to 3,500 feet of beds between the

marine-fossil horizon of the Jurassic and that of the "Permo-Carboniferous" (**11**). The upper, sandy portion of his Triassic section clearly includes the White and Vermilion Cliff sandstones, although they are not so named. The lower portion is described in general terms as "variegated, saliferous, and gypsiferous clays."

> In the midst of the clays is a bed of conglomerate. The lower shales were somewhat eroded by the current which spread it, as is shown by the inequality of the surface on which it rests. Its thickness is variable, and it is not universally present; but its persistence over large areas is nevertheless such as to excite wonder. In the conglomerate and in the superjacent clays are silicified tree trunks in great numbers. The fossil horizon discovered by Mr. Howell near Toquerville, and another that was noted south of Kanab, are lower than the Shinarump conglomerate (**11**, pp. 175, 176).

The Shinarump conglomerate appears to be definitely placed in several detailed sections published by Gilbert, between "variegated gypsiferous clays with silicified wood," above it, and "chocolate gypsiferous clays," below (**11**, pp. 158–60). On Paria Creek and at Jacob's Pool, Arizona, unconformities by erosion were noted below the conglomerate, but of no great extent, and Gilbert laid no special stress on the importance of the break indicated. Jacob's Pool is between Kanab Greek and the Paria, at the south base of the Paria Plateau.

Marvine speaks incidentally of "a conglomerate of siliceous pebbles, the Shin-ar-ump Triassic conglomerate of Powell" (**19**, p. 215). He apparently saw this bed only near St. George in Utah, near its western limit of outcrop, and on the Little Colorado, in Arizona.

Howell seems to have practically followed the Shinarump conglomerate for several hundred miles. He says:

> The conglomerate bed to which Mr. Powell has given the name Shinarump is a very singular formation. . . . . Having a maximum thickness at St. George of one hundred feet, it seldom exceeds forty or fifty to the east, but is coextensive, so far as I know, with the Trias of the Colorado Plateau. Occasionally it is little more than a coarse sandstone, and sometimes thins out to eight or ten feet, but never have I passed that horizon without seeing it. One of its constant features, almost as constant as its existence, is the great amount of silicified wood which it contains (**13**, p. 283).

Just below the ledge of the conglomerate, near Toquerville, in

southwestern Utah, a few fragments of lamellibranch shells were found by Howell. These were too imperfect for determination.

The Shinarump Group.—The comprehensive term "Shinarump Group" was proposed by Powell in 1876, in his *Geology of the Uinta Mountains*, for all the strata known to him between the upper Aubrey limestones and the Vermilion Cliff sandstone. Its Triassic age is assumed. The group is not described in much detail, the following section made by Powell "along the course of the Kanab in the winter of 1871" being the most complete statement given.

SECTION OF THE SHINARUMP GROUP, POWELL

		FEET
	Top	
11.	Bad-land sandstones, rapidly disintegrating; argillaceous; weathering in variegated hills	800
12.	Conglomerate	80
13.	Red bad-land sandstone; very friable, with much gypsum	195
14.	Greenish-gray bad-land sandstone, with much gypsum, and rapidly disintegrating	100
15.	Compact gray sandstone	8
16.	Red sandstones and arenaceous shales; gypsum in seams and joints	300
17.	Red and brown sandstone; rather thinly bedded, with many ripple marks	250
18.	Conglomerate with angular and rounded fragments of limestone in a matrix of calciferous sand	50
		1,783

The conglomerate eight hundred feet below the top of the group is evidently the one elsewhere designated Shinarump conglomerate. Powell gives no hint that an unconformity had been noted by Gilbert beneath that horizon, but he repeatedly refers to the one at the base. The upper and lower parts of the group are described in very similar terms, and fossil wood is said to characterize the whole group. It is pointed out that, "The Shinarump conglomerate is usually very hard, and weathers in such a manner as to form hogbacks or cliffs, and the softer gypsiferous beds above, when carried away by rains, leave behind fragments of this silicified wood," etc.

It is evident that Powell did not suppose that his Shinarump Group contained Permian or other pre-Triassic beds. Neither he nor any other early observer commented upon the fact that if the Shinarump conglomerate contained worn pebbles of fossil wood

there was probably a considerable difference in age between the silicified wood of the upper and lower parts of the group.

Without detailed description and with no suggestion of variation in character, Powell affirms the wide extension of the Shinarump group in the following sentence:

> The variegated beds above and below the [Shinarump] conglomerate are seen in many places on either flank of the Uinta Mountains, and from time to time this horizon is brought up by faults or flexures in all the stretch of country which intervenes between the Shinarump Cliffs and the Uinta Mountains. [**23**, p. 54]. . . . . [With regard to the Shinarump conglomerate, Powell does acknowledge that it is not easily recognizable, toward the north about twenty feet in thickness, but increasing southward until it attains two hundred feet (**23**, p. 41).]

The Shinarump as treated by Dutton in 1880.—A treatment of the Shinarump group very similar to that of Powell was given by Dutton in 1880 in his *Geology of the High Plateaus of Utah* (**6**). The range given to the group is the same, and on account of the constancy of character few descriptive details are given. Dutton thus introduces the discussion of the Shinarump:

> Resting everywhere upon the Carboniferous of the Plateau country is a series of sandy shales, which in some respects are the most extraordinary group of strata in the West, and perhaps the most extraordinary in the world. . . . . There are especially three characteristics, either one of which would render them in the highest degree conspicuous, curious, and entertaining. First may be mentioned the constancy with which the component members of the series preserve their characters throughout the entire province. Wherever their proper horizon is exposed they are always disclosed, and the same well-known features are presented in southwestern Utah, in central Utah, around the junction of the Grand and the Green, in the San Rafael Swell, and at the base of the Uinta Mountains. As we pass from one of these localities to another, not a line seems to have disappeared, not a color to have deepened or paled. . . . . The constancy is, so far as known to me, without a parallel in any formation in any other region (**6**, p. 144).

Only slight changes in thickness and in constitution are admitted. The varied coloration of different beds and the architectural forms resulting from erosion are the other two marked characteristics.

The constancy in lithologic character, the wonderful coloring, and the peculiar architecture of erosional forms here emphasized, all avowedly pertain to the lower part of the group, recognized by Dutton two years later as belonging to the Permian.

The Shinarump conglomerate is said to be within "the transitional shales" of 550 to 750 feet thickness below the Vermilion Cliff sandstone—shales not described except as "monotonous." The conglomerate is said to "consist of fragments of silicified wood imbedded in a matrix of sand and gravel." Its thickness rarely exceeds fifty feet. "It occasionally thins out and disappears, but usually recurs if the outcrops be traced onwards, resembling the mode of occurrence common to the coal seams of the Carboniferous coal measures." It is indeed suggested that the conditions under which the conglomerate was accumulated "may have been similar to those attending the formation of coal." "The subsequent silicification of the wood" is regarded as remarkable and no possibility that any part of the wood may have been derived from earlier formations seems to have been entertained (**6**, p. 147).

Walcott's section in the Kanab Valley.—In 1879, as his first work in connection with the U. S. Geological Survey, C. D. Walcott made a careful section of the formations displayed so well in the Kanab Valley, from the lower Tertiary to the pre-Cambrian of the Grand Canyon. As a result of this study, Walcott announced in 1880 the discovery of Permian fossils in the beds between the Aubrey limestone and the Shinarump conglomerate, i. e., the lower part of Powell's Shinarump Group (**24**). He found a plane of unconformity by erosion above the Aubrey, as stated by Powell, and another below the Shinarump conglomerate, as noted by Gilbert at other localities, and a third in the intermediate beds. Permian fossils were found either side of the last break.

The unconformity below the Shinarump conglomerate was further described some years later (**25**) on the basis of new observations, but the full section of the Shinarump and superjacent formations was first published in connection with a discussion of the western Colorado red beds and their correlation, by myself (**4**, p. 484). For comparison with Powell's section, also in the Kanab Valley, and that of Ward, to be given later, it seems desirable to give the section made by Walcott from the Aubrey to the Marine Jura. This I am able to do through Mr. Walcott's generosity and kindness in giving me unrestricted use of his notes

SECTION IN KANAB VALLEY, UTAH, MADE BY C. D. WALCOTT, 1879

Jurassic

FEET

1. White Cliff sandstone, massive, cross-bedded, light gray, broken into five principal belts by horizontal lines of bedding 585

Triassic

2. Vermilion sandstone; cross-bedded, friable, readily disintegrating, forming the foothills and slope to the more compact sandstones at the northern end of Vermilion Cliff Canyon 650
3. Gray and reddish-brown, cross-bedded sandstone. Horizontal beds of varying thickness divide the mass into bands of from twenty-five to one hundred feet in thickness 300
4. Evenly bedded red sandstones; upper portion an indurated, dark-reddish-brown stratum; indurated layers alternate with more friable layers and shales beneath 120
5. Massive gray sandstone, cross-bedded; upper portion is a light-gray massive friable bed. The entire mass is subdivided into six principal beds by subhorizontal lines of bedding of a dark, more indurated sandstone. The beds are from twenty to eighty feet in thickness, and may be seen on many steep escarpments along the cañon 310
6. Solid, partially cross-bedded sandstone, changing from gray to various shades of red 20
7. Evenly bedded, light-red sandstone with a thin layer of intercalated gray sandstone 20
8. Dark-red sandstone; massive layers alternating with shale, which disintegrates and forms a sloping talus to the gray sandstone beneath . 180
9. Light-gray sandstone 5
10. Bedded sandstone of various shades of red and gray. The layers of sandstone and their shaly partings are irregular in thickness. Scolithus borings occur in great numbers in a friable yellow sandstone. Fragments of vegetable matter and carbonized wood also were seen. . 230
11. Thin layers of sandstone, alternating with bands of fine argillaceous shale holding fish teeth and shells 25
12. Massive light-brown sandstone, broken up into thick layers . . 50
13. Alternating layers of sandstone and fine argillaceous shales with fish teeth, etc. 25

    A detailed section of 13 is as follows:

    a. Light sandy layers with shaly partings 7
    b. Fine, smooth, arenaceous and argillaceous shales, drab brown to red with fillets of green. A few fish scales were found 6
    c. Fine-grained, light-colored sandstone, 2 to 4 feet in thickness 4
    d. Same as (*b*), only more fossiliferous 8

14.	Reddish-brown friable sandstone, broken into layers one to six feet thick, with shaly partings	120
15.	Alternating bands of marls and shales, with layers of friable light and reddish-brown sandstone	70
16.	Reddish-brown sandstone broken up into layers two to seven feet in thickness with a stratum of gray sandstone at the base	20
17.	Arenaceous and earthy gypsiferous shales; marlites, purple, brown, bluish-green, and green, forming low, rounded foothills and slopes from the Vermilion cliffs to the Shinarump conglomerate	650
18.	Gray conglomerate and sandstone. Conglomerate formed of small, agatized pebbles and holding silicified wood	50
	Total of Triassic	2,845

UNCONFORMITY

Permian

		FEET
19.	Dark, reddish-brown, shaly sandstones, passing into a massive evenly bedded sandstone twenty feet from the summit of the bed. Ripple marks and mud cracks occur in the upper part. Erosion has removed portions of the upper shaly stratum in places, leaving an irregular surface for the conglomerate above to rest on	135
20.	Red, arenaceous shales with seams of gypsum ramifying through them in every direction	105
21.	Gray, gypsiferous marls with intercalated arenaceous shales	125
22.	Red gypsiferous marls, with a large proportion of arenaceous shales	300
23.	Impure limestone, with small fossils—Rhynchonella, Mytilus, Bakewellia, Pleurophorus, etc.	4
24.	Red gypsiferous marl	15
25.	Impure shaly limestone with arenaceous and gypsiferous shales beneath. The sandy shales thicken into layers of from two to six inches in thickness. A stratum of red marl separates this from a somewhat similar band of limestone and shales beneath. On an outlying butte, two miles from the Shinarump Cliff, the entire bed is a shaly limestone. This stratum varies in thickness, as it was deposited on the uneven surface of the beds beneath. Numerous fossils occur both in the limestone and arenaceous layers—Discina, Rhynchonella, Bakewellia, Pleurophorus, Schizodus, Myalina, Rissoa, Goniatites, Nautilus, etc., found	25
26.	Red gypsiferous marl with arenaceous shales throughout	108
27.	Yellowish sandstone with red gypsiferous shale beneath, resting in eroded hollows of the Aubrey limestone	37
	Total of Permian	854
	Total of Section	4,284

UNCONFORMITY

It is impossible to closely correlate Walcott's section with that given by Powell for the Kanab Valley (**23**, p. 53), except that the conglomerate, No. 18, is clearly the Shinarump conglomerate of Powell. It seems probable that No. 4 is the lowest member of the Vermilion Cliff group of Powell. Assuming that to be the case, it will be seen that fossil remains were found by Walcott at several horizons, in the members Nos. 10, 11, and 13, all in the upper part of the section. No fossils except silicified wood were noted in the lower 910 feet of strata assigned to the Triassic.

The fish remains obtained by Walcott in No. 13 of the above section were, at my suggestion, submitted to Dr. C. R. Eastman for examination, and he has published the following preliminary statement concerning them in connection with a discussion of the Triassic fishes of New Jersey.

> Of the few genera which are tolerably well indicated, such as *Pholidophorus* and several *Lepidotus*-like forms, it cannot be said that they evince anything in common with the Triassic fauna of the eastern states. Some resemblance is to be noted between the Kanab fish fauna and that of Perledo, near Lake Como, but the general aspect of the material collected by Walcott is much more suggestive of Jurassic than of Triassic relations. This might very well happen notwithstanding the horizon be definitely proved by stratigraphic and other evidence to be of Triassic age, as other instances of pioneer faunas and overlapping types are not uncommon. It does not appear, however, that the data thus far obtained warrants more than a plausible supposition that the Kanab beds are of Triassic age, their reddish color and relative position being consistent with what we should expect of rocks of that horizon. Accepting the evidence furnished by the fossil fishes at its full value, we shall have to regard the red beds of Kanab Canyon as belonging presumably to the Lias (**9**, p. 66 and **4**, p. 486).

The invertebrates obtained by Mr. Walcott in association with the vertebrates have been examined by Dr. H. W. Shimer, who has kindly given me (through Dr. Eastman) a report upon them. The material studied contains one indeterminable Ammonitoid fragment and two representatives of the Entomostracans. Of the latter, Dr. Shimer gives the following description:

ORDER OSTRACODA

Candona? Rogersii Jones

This species is exceedingly abundant on some bedding planes, the tests varying in length from .25^{mm} to 1^{mm}. They show variation in form, some being

regularly oval, others obliquely pointed at one end. Notwithstanding their great abundance no separation of the two valves was discernable. Remains of this species occur profusely with *Estheria ovata* in the rocks of the Newark formation of Virginia and North Carolina.

ORDER PHYLLOPODA

Estheria ovata Lea

The specimens of Estheria are of different sizes, but all agree with the characters of this species where they are distinctly recognizable. The valves are rather strongly convex, slope forward from the umbo, and are prolonged on the ventral side posteriorly. Average specimens measure 4^{mm} in length and 3^{mm} in height ($\frac{3}{16} \times \frac{1}{8}$ inch). Some specimens show considerable resemblance to *Estheria minuta* var. *brodieana* Jones, but lack the greater development of the valves anteriorly, and their lesser development posteriorly.

This species is abundant in the Newark formation of the Atlantic border.

The fossil fishes of the Kanab section undoubtedly occur some hundreds of feet above the Shinarump conglomerate, but in view of the present meager knowledge of that fauna, and considering the character of the invertebrates, as identified by Dr. Shimer, as well as the stratigraphic relations of the section, it would manifestly be premature to accept at this time the qualified suggestion of Doctor Eastman and refer the fish-bearing strata and the higher beds of the Kanab section, including the Vermilion Cliff sandstone, to the lower Jurassic.

While Walcott found no fossils except silicified wood in the Shinarump conglomerate, there is evidence that a Triassic reptilian fauna occurs locally at least in that bed or near it. This has been established by the investigations of Ward, soon to be considered.

Dutton's treatment of the Shinarump in 1882.—In his monograph on the Grand Canyon district (7) Dutton accepts the reference of the strata between the Shinarump conglomerate and the Aubrey to the Permian, in accordance with Walcott's Kanab section. From his general treatment of the subject it now becomes clear that the description of the Shinarump Group given in the *Geology of the High Plateaus*, and especially the references to its wonderful coloring and constancy of character apply most particularly to the Permian portion, for that is the part best exposed in the "Permian Terrace," as Dutton still calls the one floored by the Shinarump conglomerate. The inconvenience caused by the distribution of this conglomerate,

interfering as it does with the harmony of broad architectural features and stratigraphic geology shown elsewhere in the section, leads Dutton to humorously complain that, "Somehow we cannot help thinking that the conglomerate has no business there, and that it ought to have been cut off at the base of the Vermilion Cliffs, or else it ought to be relegated to the Permian (**7**, p. 45)."

Dutton found, and specially notes, the erosional unconformity below the Shinarump conglomerate at Pipe Spring, a few miles west of the Kanab Valley (**7**, p. 80), and in discussing various unconformities by erosion noticeable in the Plateau district says: "Perhaps the most widely spread occurrence of this kind is the contact of the summit of the Permian with the Shinarump conglomerate which forms the base of the Trias. Wherever this horizon is exposed, this unconformity is generally manifest" (**7**, p. 211).

As to the character of the Shinarump conglomerate Dutton adds little, in the publication under review, to the earlier statements. His general characterization of it is as "a light-brown, coarse sandstone, here and there passing into a conglomerate" (**7**, p. 17). There never seems to be any question as to the ability to recognize the conglomerate horizon, with Dutton or other early observers. Commenting on the uniformity of strata of the whole Plateau section, Dutton remarks that: "The curious Shinarump conglomerate is the same in Pine Valley Mountains (near St. George), in the terrace at Kanab, at the base of the Echo Cliffs, and in the land of the Standing Rocks" (**7**, p. 208). The last-named locality is about the junction of the Grand and Green rivers.

On the geological map accompanying this monograph Dutton distinguishes the Permian from the Trias, and represents both extending south along the eastern side of the Little Colorado Valley.

The Shinarump of Little Colorado Valley.—All students of the northern and eastern borders of the Colorado Plateau agree in the general view expressed by Dutton on his map that the various formations or groups between the Aubrey and the base of the Cretaceous cross the Colorado Canyon near the mouth of the Paria River, and that their outcrops extend thence southeasterly on the northeast side of the Little Colorado Valley. From the statements of Marvine

(**19**, p. 215) it would appear that the exact horizon of the Shinarump conglomerate of Powell could be recognized on the Little Colorado near the main crossing of the early route of travel. Dutton reports it at the base of the Echo Cliffs. The only detailed investigation of the Shinarump beds of this valley thus far made has, however, produced results so different from those generally accepted, and especially at variance with Walcott's section as to require some discussion.

In connection with an examination of the "petrified forests" of northeastern Arizona in 1899 and 1901, Lester F. Ward made a study of the formations either side of the Little Colorado from the Aubrey (Carboniferous) to the Cretaceous. In a paper on the "Geology of the Little Colorado Valley" (**26**) Ward assigns all beds of this section to the Triassic, the Jurassic being entirely absent, in his opinion. This supposed Triassic system embraces 3,500 feet of strata divided by Ward into three parts, according to the following generalized columnar section.

SECTION IN LITTLE COLORADO VALLEY. WARD

			FEET
Painted Desert beds	15.	White sandstones	100
	14.	Brown sandstones	200
	13.	Variegated sandstones, regularly stratified, and brilliantly colored; the well-known Painted Cliffs	800
	12.	Red-orange sandstones	100
			1,200
Shinarump Group — Leroux beds	11.	Calcareous marls, sometimes worn into buttes	200
	10.	Mortar beds, flint stones	80
	9.	Limestone ledge, definitely stratified	20
	8.	Sandstone ledge	100
	7.	Variegated marls, argillaceous and calcareous with bones of belodonts, labyrinthodonts, and dinosaurs	400
Shinarump conglomerate	6.	Conglomerate and coarse cross-bedded sandstones with clay lenses interstratified with gray argillaceous shales and variegated marls	800
			1,600

Moencopie beds	5. Dark chocolate-brown, argillaceous shales; saliferous	200
	4. Argillaceous sandstones, soft, dark brown	100
	3. Argillaceous shales, dark brown	200
	2. Calcareous shales, white	100
	1. Argillaceous shales, saliferous	100
		700
	Total	3,500

Limestone or Sandstone of Aubrey (Pennsylvanian)

In a later publication Ward revises the nomenclature of this section, speaking of the Moencopie, Shinarump, and Painted Desert *formations*, and under the Shinarump distinguishing the Leroux and Lithodendron members, the latter corresponding to the Shinarump conglomerate of his section (**27**, pp. 13–46). The term "Lithodendron member" refers to the fossil tree trunks, but is not distinctive, since these remains are also prominent in the Leroux member.

The discovery of a vertebrate fauna associated with fossil wood in a definite part of this section is certainly a most important contribution, but the systematic treatment by Ward is rather confusing as he does not attempt to harmonize his results with those of Powell, Dutton, Walcott, and others, which are, for the most part, not even referred to.

The Painted Desert formation, upon which, according to Ward, "the Cretaceous lignites and limestones lie unconformably" (**26**, p. 412) is clearly the equivalent of the Vermilion Cliff and White Cliff sandstones, although he makes no reference to earlier opinions or statements concerning the extension of these formations into the area where his section was made.

The Moencopie formation, on the other hand, corresponds in position and general character to the Permian beds found by Walcott in the Kanab section. Ward, however, found no fossiliferous limestones and makes no allusion to the work of Walcott; but if the Moencopie beds are Triassic they clearly belong in the Shinarump Group of Powell. In any case, Ward's use of Shinarump in a third sense, as a formation name for 1,600 feet of strata, seems unwarranted.

The correlation of eight hundred feet of sediments of variable character, grading into marls in some places, with the Shinarump conglomerate, is a procedure requiring clear justification by facts of

observation not to be found in Ward's papers. It is plain that Powell applied the name to a particular conglomerate seldom found to exceed more than one hundred feet in thickness and that all other writers I have cited, with the exception of Ward, have used the term for what they believed to be the same conglomerate. It appears to be impossible to locate the actual horizon of the Shinarump conglomerate in the Shinarump formation of Ward, yet, as the ensuing discussion will show, it is particularly important to ascertain the relation of the beds containing the reptilian fauna discovered by Ward to the Shinarump conglomerate of earlier investigators.

For reasons to be developed, it appears to me not improbable that the horizon of the Shinarump conglomerate proper is near the beds in which the vertebrate fossils were found, possibly at the base of the Leroux member of Ward. The statements of Powell and Dutton indicate that the conglomerate may become inconspicuous through thinning and that it may locally disappear as a conglomerate. Its horizon may be difficult of detection where the conglomerate phase is absent.

If it be assumed for the moment that the eight hundred feet of beds designated by Ward the Lithodendron member are below the horizon of the Shinarump conglomerate proper, there is reason to believe that those eight hundred feet of strata belong in truth with the Moencopie beds, the transition reported by Ward in Red Butte having the significance suggested for it by him. On this same assumption the Leroux beds of Ward fall into place as the lower Triassic of the Little Colorado Valley.

No fossils surely belonging to the Moencopie formation were found by Ward. Fossil wood is common in both members of the Shinarump. The celebrated "petrified forest" in which large prostrate silicified trunks are abundant represents more than one stratigraphic horizon. The so-called "upper" and "lower" forests are said to be in the Lithodendron beds, while the "middle" forest is in the Leroux member. As but one species of the silicified wood has been identified this abundant material is of little diagnostic value at present. The single species studied is *Araucarioxylon arizonicum Knowlton* (**15**), based on two fossil trunks collected by Lieutenant Hegewald, in 1879, of which the horizon of occurrence is unknown.

It seems to be assumed by Ward, as by others, that the occurrence of fossil wood throughout his Shinarump formation is an indication of its unity. But until these woods have been studied the correctness of that view is open to question. The presence of rounded pebbles of silicified wood in the Shinarump conglomerate has been asserted by several observers, and, if true, this fact alone must cause critical comparison of the fossil trunks occurring above and below this horizon.

The only tree trunks found by Ward in vertical position, as though in the place of growth, were in the Leroux beds very near the locality at which the best vertebrate remains were found, east of Tanner's crossing of the Little Colorado.

Vertebrate remains were found by Ward and Brown only in the Leroux beds and mostly in their lower portion. The principal localities from which they were collected by Brown for the National Museum are a few miles east or north of Tanner's Crossing, but they were noted at other places, including the "petrified forest." The material has been examined and partially described by Lucas (**17** and **18**), the forms identified by him being the following:

Two belodont crocodiles, *Episcoposaurus* sp.? Cope, and *Heterodontosuchus ganei*, Lucas, the type of which came from the San Juan Valley, Utah; *Metoposaurus fraasi*, Lucas, n. sp., *Placerias hesternus*, Lucas, n. sp., and *Palaeoctonus* sp.? Cope.

This fauna is in Lucas' opinion a distinctly upper Triassic one. He remarks that:

> Aside from the interest attached to the finding of this new species (of *Metoposaurus*) is the more important fact pointed out by Dr. Fraas (personally) that the genus *Metoposaurus* is characteristic of the Keuper of Europe, and that we have in these Triassic beds of Arizona, Utah, and Wyoming the same combination of belodont and labyrinthodont as in the Keuper (**18**, p. 195).

He might have added that the fauna is clearly present in the Dolores formation of Colorado.

Ward states that Brown found "a small number of shells and a few other invertebrates" with the vertebrate remains, but since their diagnostic value was questioned by Ward, they do not seem to have been submitted to a specialist for examination. Mr. T. W. Stanton informs me that the only invertebrates now in Brown's collection in the National Museum are Paleozoic brachiopods, corals, etc., in

pebbles. It is not certain that Ward referred to this material, the significance of which is not known.

Comparing the results obtained by Walcott and Ward in portions of the Colorado Plateau not many miles apart and where all earlier geologists have given the impression that the formations change but little from place to place, we find in fact remarkable differences. Walcott established an unconformity below the original Shinarump conglomerate; he discovered no vertebrate fossils in or near that stratum; but 910 feet above it, below the Vermilion Cliff sandstone, he found fish remains of unique character suggesting to the specialist Jurassic rather than Triassic affinities. Ward, on the other hand, finds at 400 to 800 feet below the Vermilion Cliff the Triassic reptilian fauna characterizing the basal portion of the Dolores formation through western Colorado and on Grand River; he noted no unconformity near this vertebrate horizon and does not recognize the Shinarump conglomerate of Powell, Walcott, and others. These discrepancies demonstrate that there is room for much further study of the Shinarump and associated formations in northern Arizona.

The lower Trias of the Zuñi Plateau.—The continuity of Mesozoic and upper Paleozoic formations from the vicinity of the Grand Canyon into northwestern New Mexico is a subject on which all geologists who have examined the region are agreed. In his report on the Zuñi Plateau, Dutton (**8**, p. 134) identifies 450 feet of strata as Permian, through the presence of fossils mentioned as *Bakewellia* and *Myalina* (without specific identification) and from the stratigraphic position of the beds between the Aubrey and a sandstone identified by Dutton as the Shinarump conglomerate. The identification is not convincing, for the only descriptive terms employed are of general application and indicate a character which one cannot suppose to be persistent. The Shinarump conglomerate is referred to by Dutton, in speaking of its general character, as "a well-marked, coarse sandstone," and as "a very coarse conglomeratic sandstone." The only statement of its character in the Zuñi Plateau is in the first three words of the following sentence: "The coarse sandstone, equivalent, I believe, to Powell's Shinarump conglomerate, will be for the present the provisional base of the [Triassic] series" (**8**, p. 135). In view of Ward's statement that conglomeratic beds appear variably through some

eight hundred feet of strata, on the Little Colorado, one may question the correctness of Dutton's identification of this datum horizon. This doubt is strengthened by the statement that for 650 feet above the "conglomerate" the "strongly-colored sandy shales abounding in selenite and silicified wood . . . . resemble so exactly the Permian below that it is quite impossible to distinguish them lithologically" (**8**, p. 135). Between these shales of Permian aspect and the Wingate sandstone which Dutton correlates with the Vermilion Cliff occur eight hundred to nine hundred feet of strata which are rarely so well exposed that their character can be ascertained. They are referred to as "lighter colored, pale, dull-red shales." It seems inherently probable that the base of the Triassic series is in this ill exposed part of the section, not far below the Vermilion Cliff or Wingate sandstone.

The original sweeping assertions of Powell and Dutton that the Shinarump Group, including all beds between the Aubrey and the Vermilion Cliff, extends, in almost unmodified development, north through the Plateau country to the Uinta Mountains were based on insufficient knowledge. There is much evidence to show that the strata of the section in question do not preserve that wonderful constancy of character, nor the uniform thickness to be inferred from Dutton's words, which have been quoted. This holds true for both Triassic and Paleozoic parts of the section.

Let us first review the knowledge concerning these deposits in the upper reaches of the cañon of the Colorado, and of its branches, the Grand and Green Rivers.

Vicinity of the Henry Mountains.—Going up the Colorado less than seventy-five miles above the mouth of Paria River, where Powell, Dutton, Gilbert, and others have examined the section, we come to the area included in Gilbert's study of the Henry Mountains. For that area he has given the following general section of the Shinarump Group (**12**, p. 6).

	Top	FEET
a.	Variegated clay shale; purple and white above and chocolate below, with silicified wood	300
b.	Gray conglomerate, with silicified wood; the Shinarump conglomerate	30
c.	Chocolate-colored shale, in part sandy	400
		730

Beneath this section comes the Aubrey sandstone; above it is the Vermilion Cliff sandstone.

This section is materially different from those given by Powell, Walcott, and Ward, but no explanation is offered by Gilbert. He states that evidence of unconformity below the Shinarump conglomerate was not found in the Henry Mountains, but if only four hundred feet of strata there intervenes between the conglomerate and the fossiliferous Aubrey, there is reason to believe that the stratigraphic break at that horizon is considerable.

The constitution of the beds assigned to the Shinarump is certainly different from that of the typical section of the Kanab. There is nothing said of sandstones on the one hand or gypsiferous beds on the other.

The Lower San Juan Valley.—In connection with this Henry Mountains section, it is well to consider the observations made by H. S. Gane on the northern side of San Juan River, near the Colorado, which I made public in an earlier discussion of the red beds of the Plateau Province (**4**, p. 476). Gane traced several Mesozoic formations down the San Juan Valley from the head of McElmo Creek in Colorado, a point very near the La Plata quadrangle, where he had assisted in the study and mapping of those formations, under my direction (**2**). Among the formations, the continuity of which to the Colorado Canyon seemed clear to Gane, is the Dolores Triassic formation, at the base of which and recurring irregularly in the lower sandstone is a fine-graided conglomerate consisting largely of limestone pebbles and carrying teeth and fragments of bones of several vertebrates. Tracing this fossiliferous zone down the valley, Gane found in it at Clay Hill divide, about twenty miles east of the northern end of Glen Canyon, a portion of a crocodile jaw, unusually well preserved. This specimen was described by Lucas (**16**) as the type of *Heterodentosuchus ganei.* This form is the most abundant one in the collection made by Ward and Brown in the Leroux beds and it is also very common in the Dolores formation in the San Juan region of Colorado, as appears from the work in my charge. Unios were noted by Gane associated with the vertebrate.

There is no means of proving that the conglomerate called the Shinarump by Gilbert in his section is the same as that carrying

crocodilian remains at Clay Hill, but, from the ensuing discussion, it will seem not at all unlikely that such is the case.

Newberry's Grand River section.—Where the Colorado begins, at the junction of Grand and Green Rivers, about forty-five miles northeast of the Henry Mountains, is one of the points cited by Dutton at which the Shinarump Group is typically developed (see p. 103) and where he says the Shinarump conglomerate is found in its characteristic form. Aside from the very general statements of Powell (**22**), I can find nothing in the literature of the Plateau Province recording observations made at this locality. Dutton refers to Newberry's description of the formations on Grand River some miles above the junction with the Green. The vivid pen pictures of the scenery and of the broader stratigraphic features given by this earlier explorer of the region do indeed agree very well with those of Powell, but it is difficult to recognize the Shinarump of Arizona in the section Newberry gives of the possible Triassic beds. He found fossiliferous Carboniferous strata (which Dutton and Powell considered as Aubrey) in the Grand River Canyon where he descended to the stream,[1] and measured the superjacent section of red beds in "Cañon Colorado," the side gorge traversed in making the descent. This section follows (**20**, p. 99):

SECTION IN CAÑON COLORADO, UTAH (NEWBERRY)

		FEET
9.	Red and brown massive sandstone, fine-grained, not hard. No fossils	270
10.	Soft red sandstone, in thin layers, separated by beds of red or dark brown shales	350
11.	Greenish-gray micaceous conglomerate and gray sandstone, separated by red and purple shales	92
12.	Soft liver-colored sandstones, becoming suddenly and locally nearly white, with partings of shale	350
13.	Brick-red massive calcareous sandstones, with some like the last.	164

As I have explained in the paper on a reconnaissance to Grand River, at Moab (**5**, p. 644), the strata under No. 9 of Newberry's section clearly belong to the lower part of the La Plata or White Cliff

[1] Newberry believed that the side cañon descended by him to Grand River was but a few miles above the union with Green River. But it seems from most recent maps that the "Cañon Colorado," in which Newberry's route lay, enters Grand River cañon about twenty-four miles above Green River, and only about nine miles below the present site of Moab.

Jurassic sandstone, and No. 10 to the Vermilion Cliff sandstone. Possibly No. 11 contains the Shinarump conglomerate. If so, it would appear that the Triassic portion of the Shinarump is represented by but ninty-two feet of beds at this point. On that basis Newberry's section is in close agreement with that a few miles farther up Grand River, next to be considered. But Nos. 12 and 13 are quite unlike the strata underlying the Shinarump conglomerate in Arizona. Fossil wood was not mentioned by Newberry in any of the strata assigned to the Trias. These considerations show that that part of the section on lower Grand River corresponding to the Shinarump in stratigraphic position does not in fact resemble the typical section of that group closely in any particular.

Grand River Valley near Moab.—That the generalization just expressed is correct has been amply demonstrated by an examination by myself and associates of the formations exposed in the Grand River Valley near Moab and for about twenty five miles above that point. I have recently published (**5**) the results of that reconnaissance, made in 1905, and need here repeat only the salient facts affecting the question of the Shinarump.

The Vermilion Cliff and White Cliff sandstones, of the general character noted by Powell, are unmistakable datum formations from which to start in stratigraphic studies in Grand River Valley. Below the former, however, we found many things at variance with the idea of simplicity and regularity in this part of the section. Opposite Moab on the northwest side of Grand River the section exposed below the Vermilion Cliff sandstone is as follows:

SECTION NEAR MOAB, UTAH

		FEET
	Top, Vermilion Cliff Sandstone	
12.	Sandstone, massive or shaly, dark red at base and bright red at top	20
11.	Shaly, conglomeratic sandstone with numerous reddish limestone pebbles the size of a pea or smaller; a few small bone fragments	6
10.	Sandy shales, red and green	5
9.	Débris slope apparently representing red shale	20
8.	Limestone conglomerate, with a few inches of limestone at top; fossil wood and bone fragments; pebbles less than two inches diameter	10
7.	Sandstone, gray, massive	20
		81

	Carried forward	81
6.	Limestone conglomerate, grading into sandstone	1½
5.	Sandstone, gray, massive, becoming shaly near top	23
4.	Calcareous sandstone with fine-grained conglomerate near base and top; pebbles of limestone and sandstone with occasional bone fragments; pebbles vary from size of a pea to several inches diameter	9
3.	Red sandy shale alternating with sandstone	8
2.	Conglomerate containing pebbles of limestone and sandstone	1
1.	Sandstone and shale alternating, red and green, the shales sandy and friable	35
		158½

Beneath No. 1 of this section is a blue limestone carrying coral (Zaphrentis), and, in all, 380 feet of Pennsylvanian beds are exposed, consisting of alternating sandstones and limestones, with abundant fossils. No unconformity was noticeable between the coralline limestone and the overlying sandstone and it is not certain whether Nos. 1, 2, and 3 of the above section should be included with the Carboniferous or not.

The point to be emphasized is that for somewhat more than one hundred feet below the Vermilion Cliff in this section the beds present the characteristics of the lower part of the Dolores formation of Colorado rather than of anything hitherto described from the Shinarump. There is at most only about forty-five feet of beds referable to any formation between the Pennsylvanian and Dolores.

In Grand River Canyon, twelve miles above Moab, the bone-bearing limestone-conglomerate series is found in marked angular unconformity with the underlying beds and it is probable that two thousand feet of strata consisting of two groups of sandstones, conglomerates, and shales, separated by a gypsiferous-shale series, are present between the Pennsylvanian and Dolores strata. No fossils were found in these intermediate beds, but they seem to correspond to the strata of possible Permian age known in Colorado between the Dolores and Hermosa (Pennsylvanian) formations, and collectively termed the Cutler formation in the San Juan folios (3).

We found no specifically determinable bones in the beds below the Vermilion Cliff on Grand River. The best obtained was a crushed vertebra belonging, according to Mr. Gidley, to a Triassic form of carnivorous Dinosaur, or possibly to a belodont crocodile. The

fragmentary condition of the remains and the rarity of determinable specimens is, however, entirely analoguous with the occurrence of similar material in the Dolores beds in Colorado.

Poorly preserved Unios are common in the Dolores formation and we observed very similar undeterminable shells in the conglomerate with bone fragments, at Moab. Three species of Triassic Unios in a much better state of preservation were found some years ago on Grand River very near the Vermilion Cliff sandstone by L. M. Prindle (**5**, p. 653), and there is no basis for doubting that they came from the bone-bearing series of beds.

With this knowledge of the Moab and Grand River sections, it seems almost certain that the ninety-two feet of strata embraced under No. 11 of Newberry's section represent the series of bone-bearing conglomerates, etc., which we refer to the Dolores formation. The absence of the gypsiferous shales and of the overlying conglomerates, sandstones, and shales, indicates a stratigraphic break in Newberry's section and the probable horizon of the break is beneath No. 11.

Uinta Mountains.—The statements of Powell and Dutton that the Shinarump Group is typically developed on the flanks of the Unita Mountains are without confirmation in the descriptions of the strata referred to the Triassic by these authors or the geologists of the Fortieth Parallel Survey. Powell refers 1,095 feet of beds west of Flaming Gorge to the Shinarump and describes them briefly as follows: "Shales and sandstones containing much gypsum; weathering in many colors, but brown and chocolate tints prevailing; in many places constituting bad-land beds" (**23**, p. 152). There is no suggestion of the Shinarump conglomerate in this section.

It is clear that Powell included in the Shinarump of the Uintas the beds called Permo-Carboniferous by the Fortieth Parallel geologists, and Permian by Dutton in his Grand Canyon monograph, and the description above cited seems to apply to those strata. There is no known evidence that the fossiliferous horizon found at Moab is present on the Uinta slopes, but the discovery reported by Williston (**28**) of a Triassic vertebrate fauna in Wyoming closely related to, if not identical with, that from the Little Colorado Valley and the Dolores formation makes it not improbable that closer study will

disclose the fossiliferous horizon in the Uinta Mountains. From the relations found on Grand River, it seems probable that the equivalent of the "saurian conglomerate" occurs near the Vermilion Cliff sandstone if present at all in the Uinta section.

The only statement I have found in regard to the Trias of the Uintas suggesting the presence of the fossiliferous horizon of the Dolores formation, or, as it might be otherwise interpreted, of the Shinarump conglomerate, is a passage from King's description of the section on the northern slopes of the mountains near Vermilion Creek. He remarks that the basal portion of the Trias consists "of red conglomerate-bearing sandstones which carry a seam of drab limestone. Above these is a body of red sandstone of several hundred feet" (**14**, p. 259). This heavy sandstone seems to correspond to the Vermilion Cliff sandstone, for above it comes a lighter-colored cross-bedded sandstone answering to the White Cliff or La Plata sandstone. Emmons describes the same section in similar terms (**10**, p. 275). Presumably the "conglomerate-bearing sandstone" is quite near the Vermilion Cliff and this at once suggests comparison with the Grand River section.

The foregoing discussion has not taken into account the lower Triassic beds of southeastern Idaho, often termed the "Meekoceras beds" from characteristic marine fossils they contain. These beds are not known in any of the areas referred to in this paper. If ever present in Colorado or the Plateau Province the marine lower Triassic beds must have been removed by the pre-Dolores erosion. The interesting problem as to the relations of the Meekoceras beds to the so-called Permian or Permo-Carboniferous formations of Utah is clearly beyond the scope of this paper.

It is hoped that the foregoing discussion will have made clear to the reader that there are strong reasons for correlating the Triassic portion of Powell's Shinarump Group with the lower part of the Dolores formation of Colorado. The fossiliferous "saurian conglomerate" of the Dolores has been traced into the heart of the Plateau country and a notable unconformity found below it there as well as in the San Juan Mountains of Colorado. The reptilian fauna of the "saurian conglomerate" has been found on the Little Colorado,

at a horizon corresponding closely to that at which the Shinarump conglomerate must come, and at a point only about sixty miles southeast of typical exposures of that conglomerate in the cliffs of the Paria Plateau. On stratigraphic grounds it appears probable that the Shinarump conglomerate and the "saurian conglomerate" occur at the same horizon.

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